Status and extension of FLASH

Josef Feldhaus

HELMHOLTZ GEMEINSCHAFT

European XFEL / HASYLAB Users' Meeting
DESY, January 26, 2012

DESY

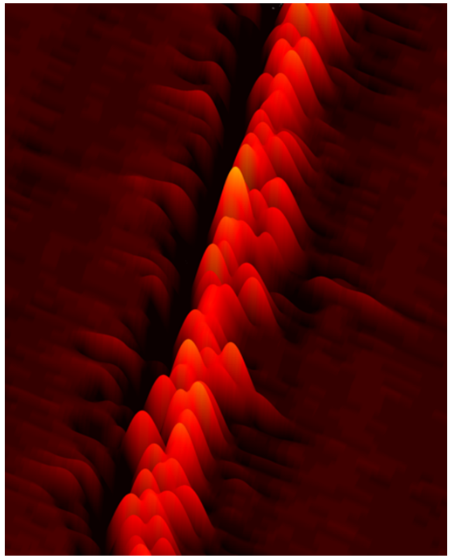
Outline

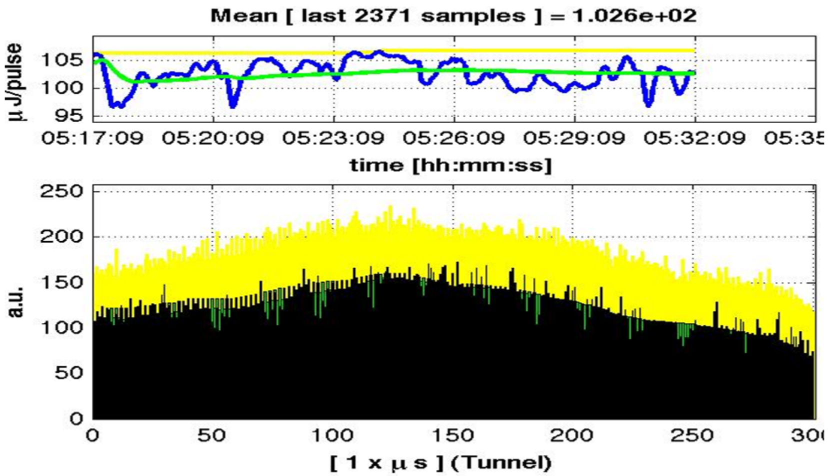
- Overview of 3rd user run
- Status of the FLASH II project
- Future developments

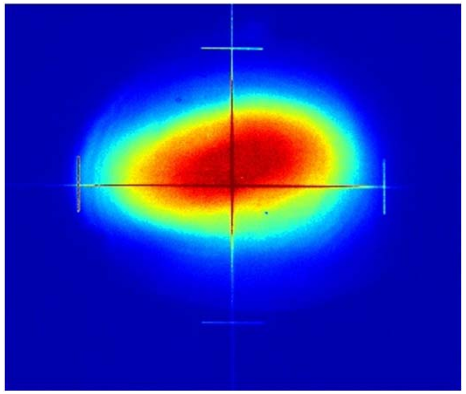
FLASH Parameters 2011

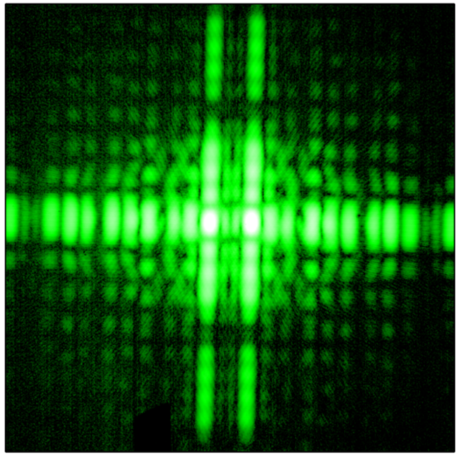
FEL Radiation Parameters 2011	
Wavelength range (fundamental)	4.1 – 45 nm
Average single pulse energy	10 – 400 µJ
Pulse duration (FWHM)	50 – 200 fs
Peak power (from av.)	1 – 3 GW
Average power (example for 3000 pulses/sec)	~ 300 mW
Spectral width (FWHM)	~ 0.7 - 2 %
Average Brilliance	$10^{17} – 10^{21}$ *
Peak Brilliance	$10^{29} – 10^{31}$ *

* photons/s/mrad²/mm²/0.1%bw







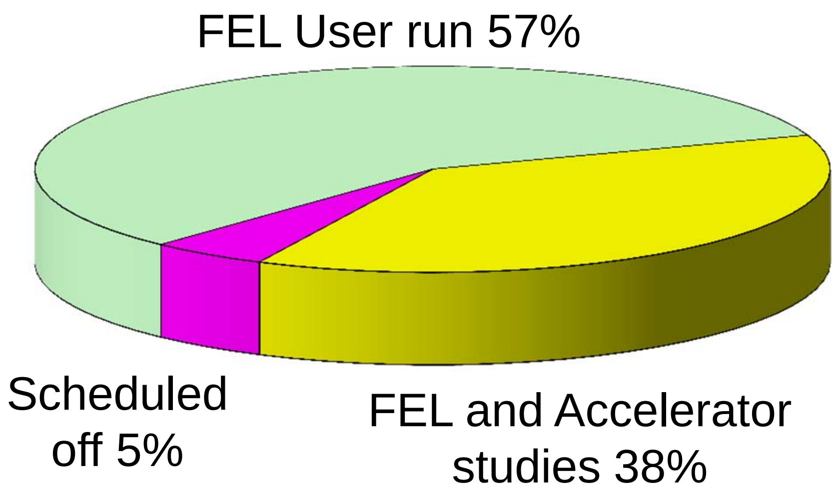


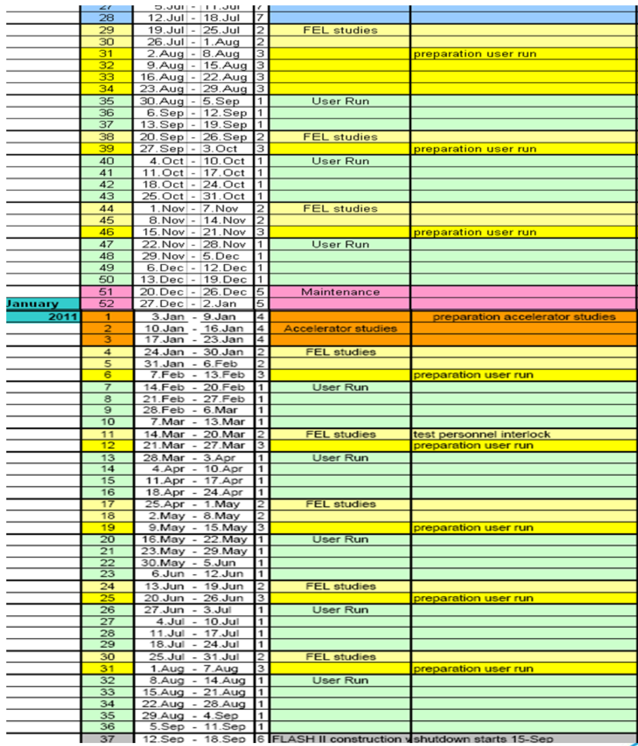
- 150 publications on photon science at FLASH, many in high impact journals

  http://hasylab.desy.de/facilities/flash/publications/selected_publications

3rd User period

- Sep 2, 2010 – Sep 5, 2011
- 75 proposals reviewed,
  29 proposals accepted
- 307 x 12 h-shifts scheduled
  plus ~20 % for in-house experiments
  and contingency
  - 8 user blocks of ~ 4 weeks each





	27	5.Jul - 11.Jul	7		
	28	12.Jul - 18.Jul	7		
	29	19.Jul - 25.Jul	2	FEL studies	
	30	26.Jul - 1.Aug	2		
	31	2.Aug - 8.Aug	3		preparation user run
	32	9.Aug - 15.Aug	3		
	33	16.Aug - 22.Aug	3		
	34	23.Aug - 29.Aug	3		
	35	30.Aug - 5.Sep	1	User Run	
	36	6.Sep - 12.Sep	1		
	37	13.Sep - 19.Sep	1		
	38	20.Sep - 26.Sep	2	FEL studies	
	39	27.Sep - 3.Oct	3		preparation user run
	40	4.Oct - 10.Oct	1	User Run	
	41	11.Oct - 17.Oct	1		
	42	18.Oct - 24.Oct	1		
	43	25.Oct - 31.Oct	1		
	44	1.Nov - 7.Nov	2	FEL studies	
	45	8.Nov - 14.Nov	2		
	46	15.Nov - 21.Nov	3		preparation user run
	47	22.Nov - 28.Nov	1	User Run	
	48	29.Nov - 5.Dec	1		
	49	6.Dec - 12.Dec	1		
	50	13.Dec - 19.Dec	1		
	51	20.Dec - 26.Dec	5	Maintenance	
January	52	27.Dec - 2.Jan	5		
2011	1	3.Jan - 9.Jan	4		preparation accelerator studies
	2	10.Jan - 16.Jan	4	Accelerator studies	
	3	17.Jan - 23.Jan	4		
	4	24.Jan - 30.Jan	2	FEL studies	
	5	31.Jan - 6.Feb	2		
	6	7.Feb - 13.Feb	3		preparation user run
	7	14.Feb - 20.Feb	1	User Run	
	8	21.Feb - 27.Feb	1		
	9	28.Feb - 6.Mar	1		
	10	7.Mar - 13.Mar	1		
	11	14.Mar - 20.Mar	2	FEL studies	test personnel interlock
	12	21.Mar - 27.Mar	3		preparation user run
	13	28.Mar - 3.Apr	1	User Run	
	14	4.Apr - 10.Apr	1		
	15	11.Apr - 17.Apr	1		
	16	18.Apr - 24.Apr	1		
	17	25.Apr - 1.May	2	FEL studies	
	18	2.May - 8.May	2		
	19	9.May - 15.May	3		preparation user run
	20	16.May - 22.May	1	User Run	
	21	23.May - 29.May	1		
	22	30.May - 5.Jun	1		
	23	6.Jun - 12.Jun	1		
	24	13.Jun - 19.Jun	2	FEL studies	
	25	20.Jun - 26.Jun	3		preparation user run
	26	27.Jun - 3.Jul	1	User Run	
	27	4.Jul - 10.Jul	1		
	28	11.Jul - 17.Jul	1		
	29	18.Jul - 24.Jul	1		
	30	25.Jul - 31.Jul	2	FEL studies	
	31	1.Aug - 7.Aug	3		preparation user run
	32	8.Aug - 14.Aug	1	User Run	
	33	15.Aug - 21.Aug	1		
	34	22.Aug - 28.Aug	1		
	35	29.Aug - 4.Sep	1		
	36	5.Sep - 11.Sep	1		
	37	12.Sep - 18.Sep	6	FLASH II construction v	shutdown starts 15-Sep

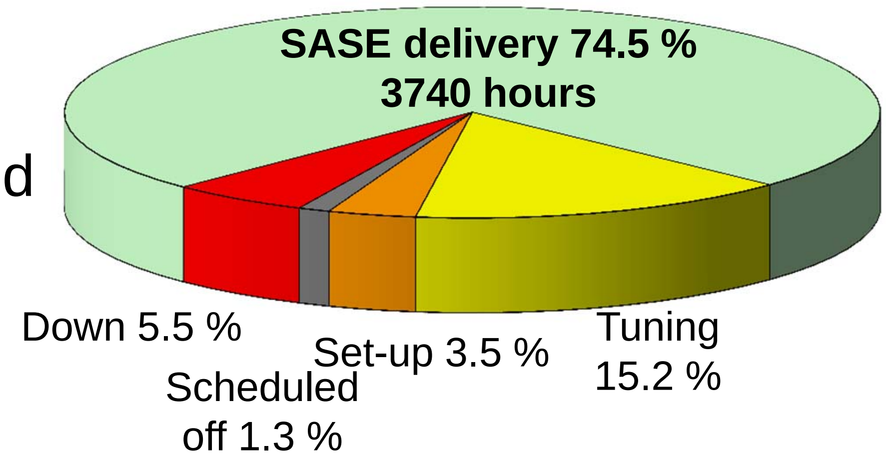
Requested Pulse Pattern	
Single bunch	47 %
multi-bunch with different bunch spacing	53 %

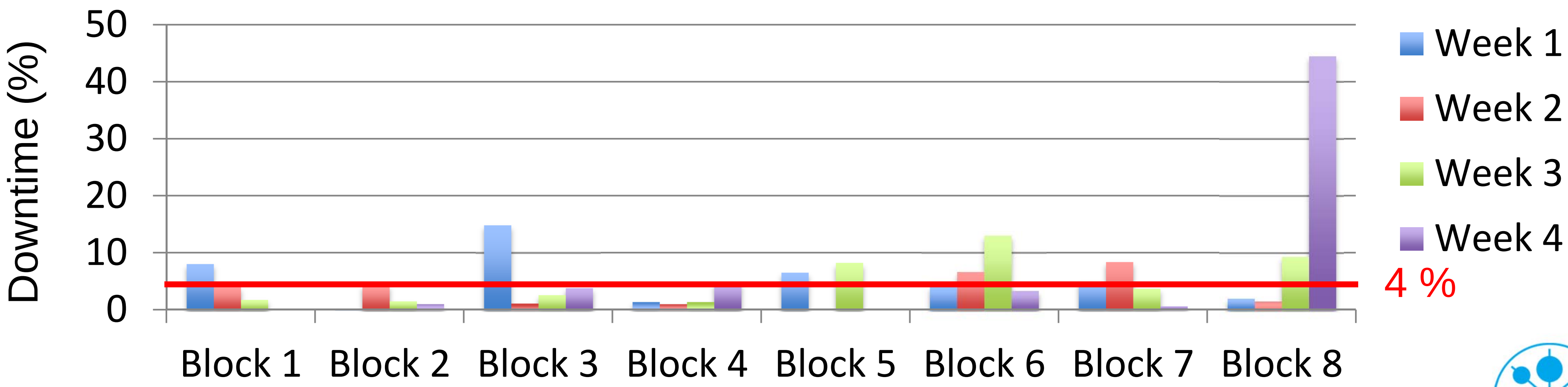
Requested FEL pulse duration		
	< 50 fs fwhh	28 % (*)
	50 -100 fs	54 %
	not critical, but high intensity	18 % (**)

(*) 72 % multi-bunch (**) mostly multi-bunch

Beam delivery during user time

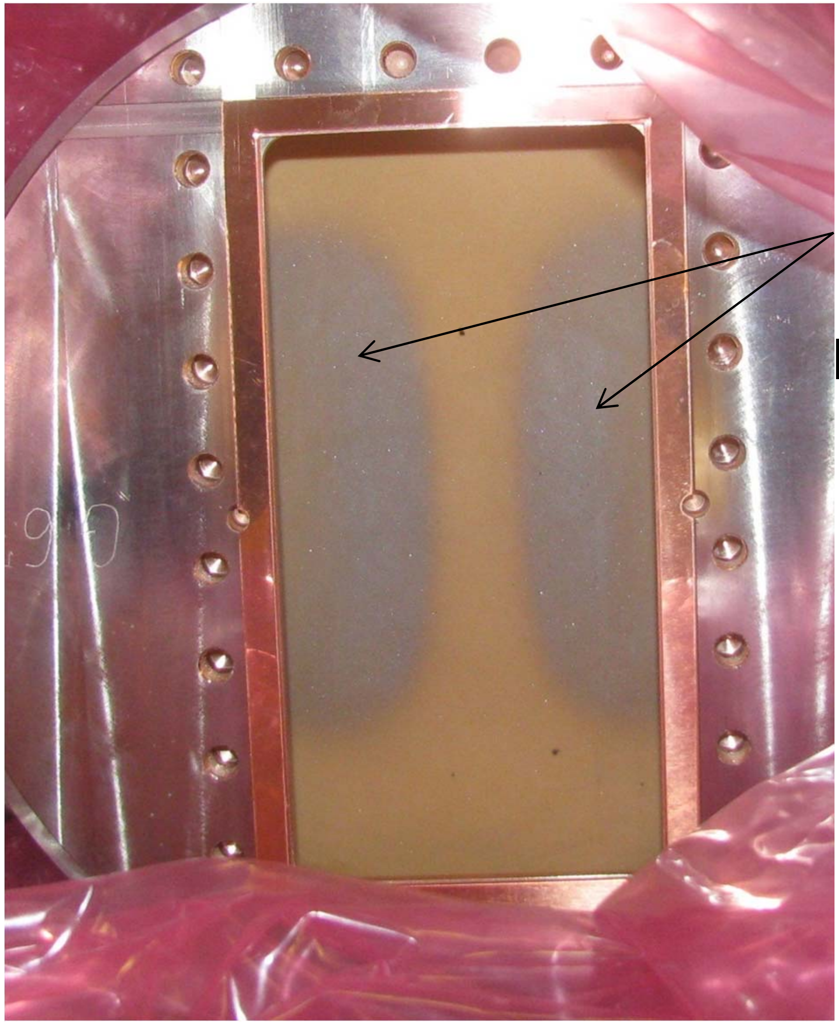
- 8 User blocks scheduled with 4955 hours
- 3740 hours of SASE delivery (user and in-house experiments)
- 3686 h scheduled for external users,
  3628 h delivered (98 %)
- Down time and tuning largely compensated
  by using in-house, contingency,
  and maintenance shifts
- Run stopped on Sep 5, 9am,
  due to RF-gun failure





RF-Window after dismounting

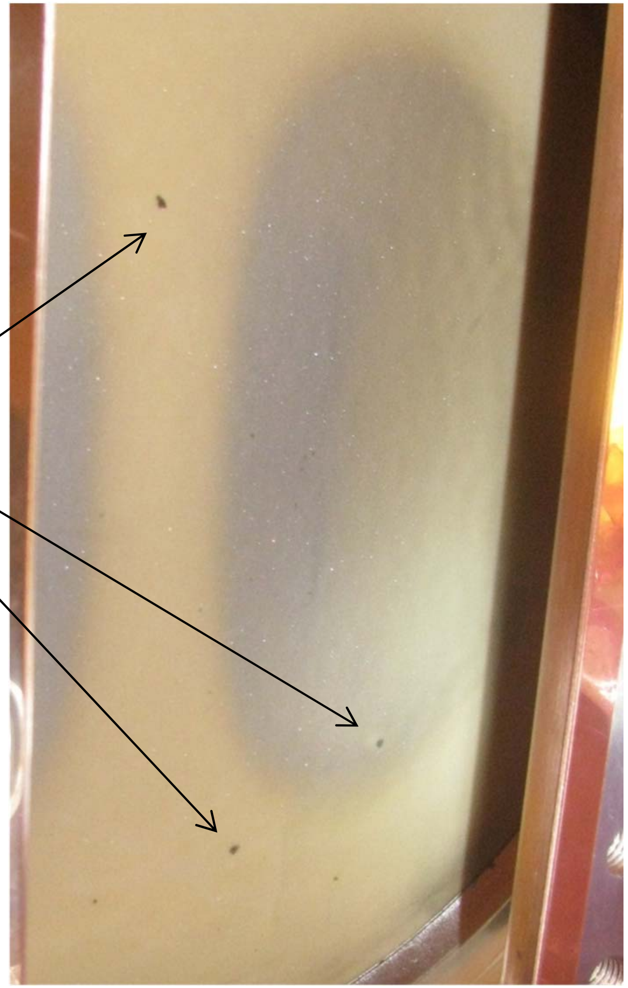
Vacuum side



Pattern which indicates the high field region (dipole field)

Many particles/dark spots visible

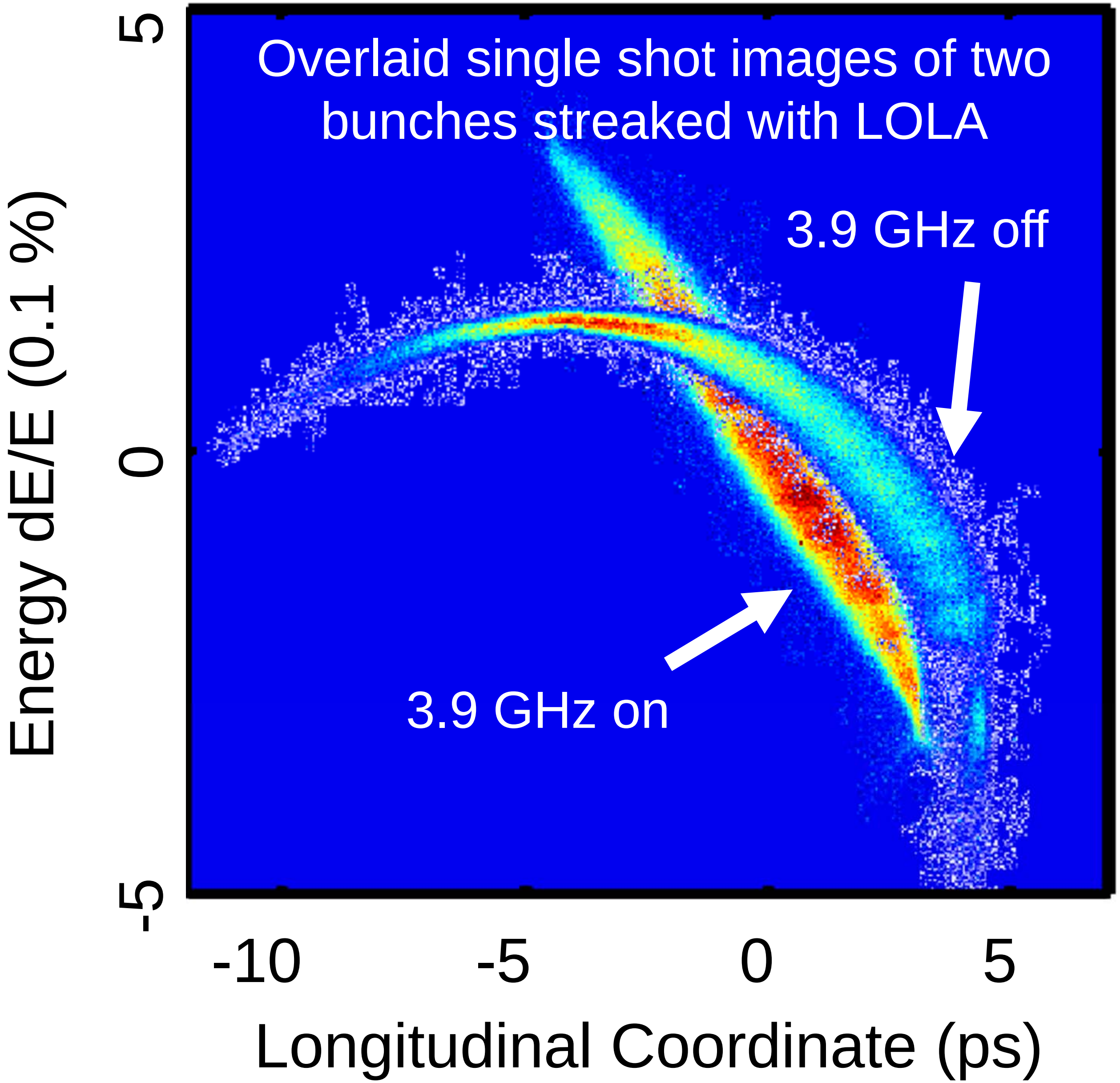
Dark area most likely metallization which is a definite risk of operation



3.9 GHz (3^{rd} harmonic) Module and Module 1

- New 1^{st} accelerating module with improved cavities and Piezo tuners
- 3^{rd} harmonic module with four nine-cell superconducting cavities operated at 3.9 GHz
  - includes RF system and LLRF regulation
  - built at FNAL (Fermilab) in a collaboration with DESY

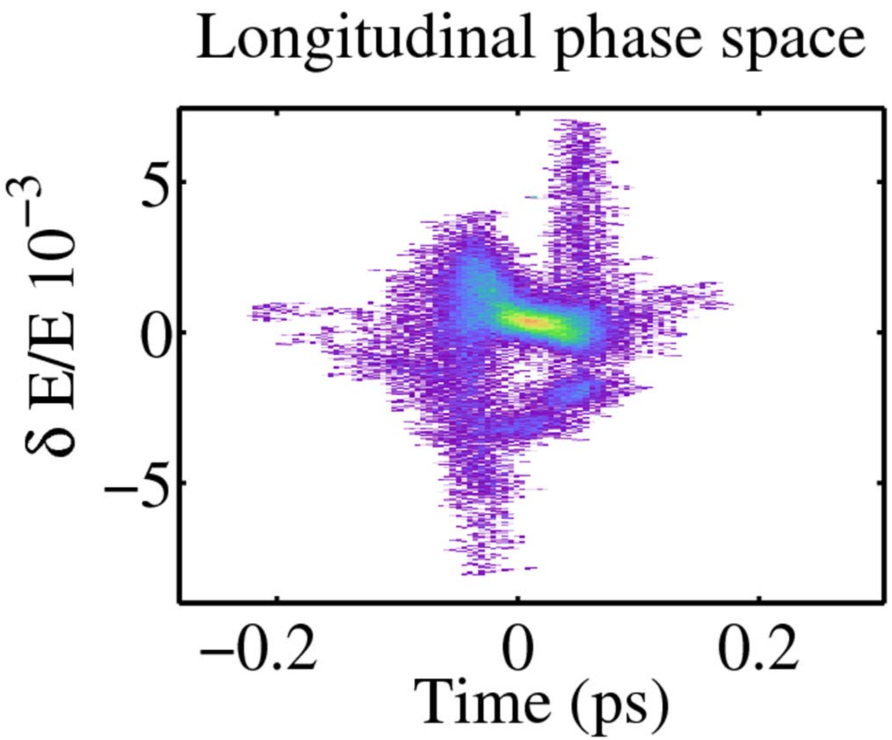
Bunch compression using 3rd-harmonic cavities

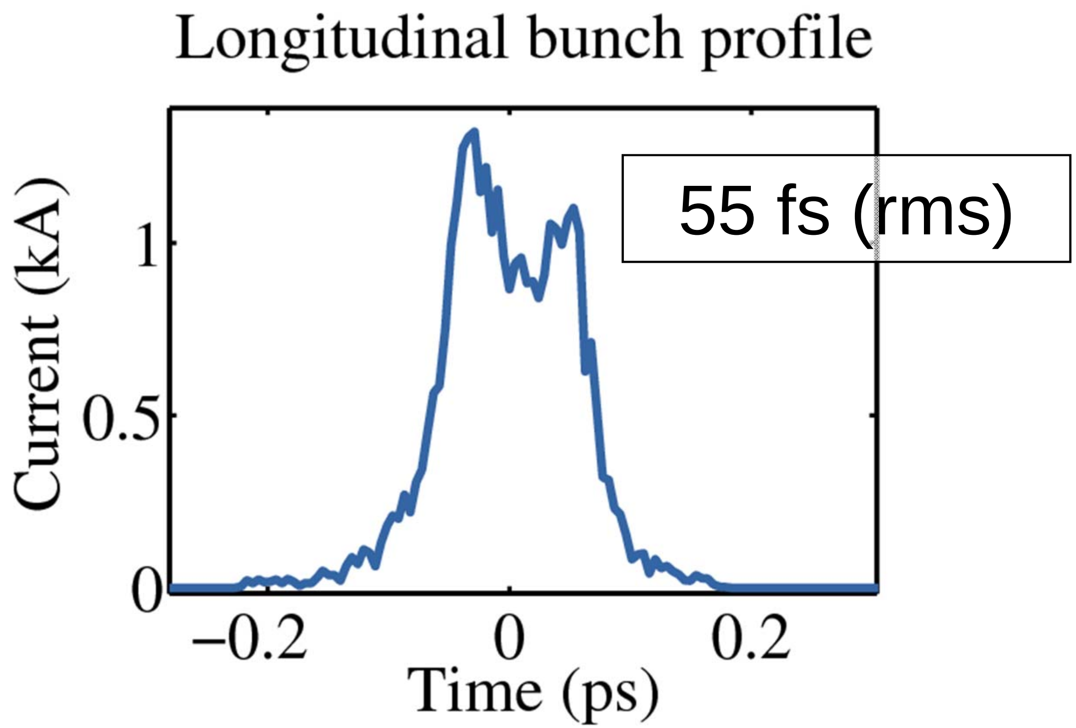


- measured with LOLA,
- dispersive section
- beam energy 700 MeV
- slight compression with 1st module (ACC1)
- 3.9 GHz cavities on/off

Example of longitudinal electron bunch profile

Phase space distribution measured with LOLA (bunch charge 200 pC)

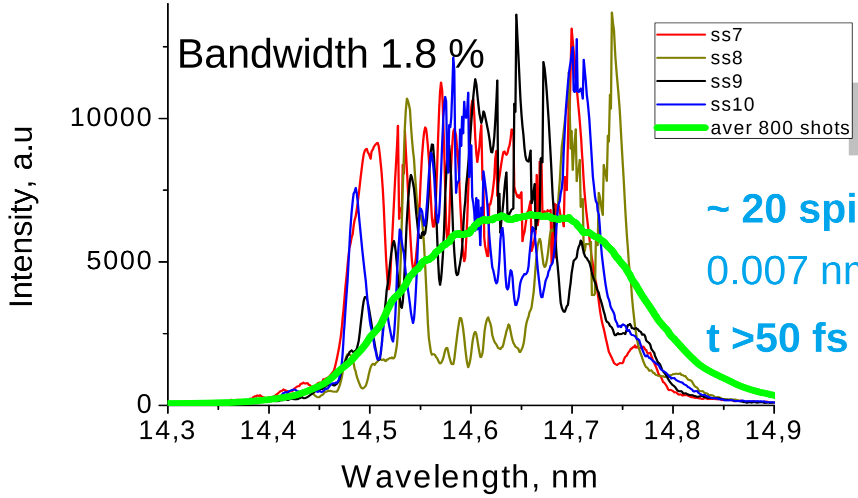




Spectra at different bunch charges

Linear regime

500 pC

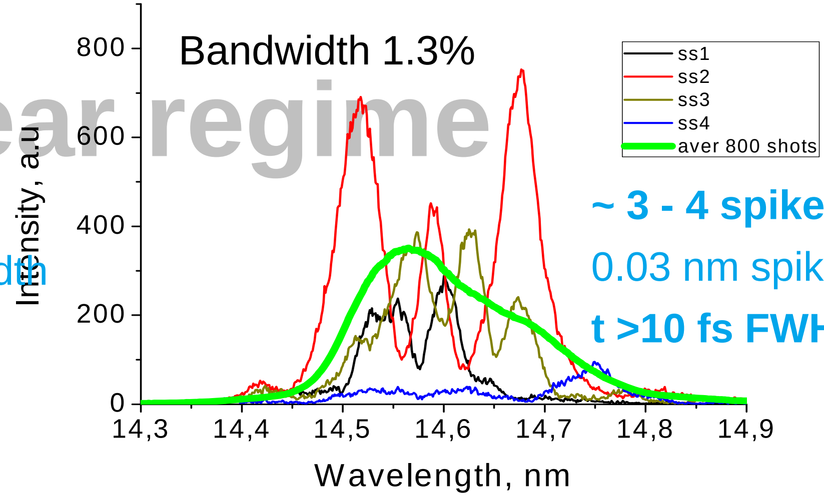


~ 20 spikes

0.007 nm spike width

t >50 fs FWHM

150 pC

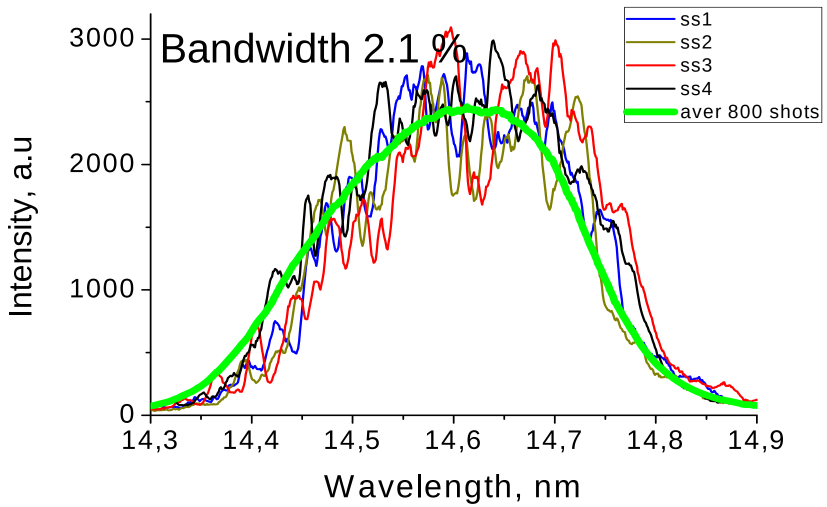


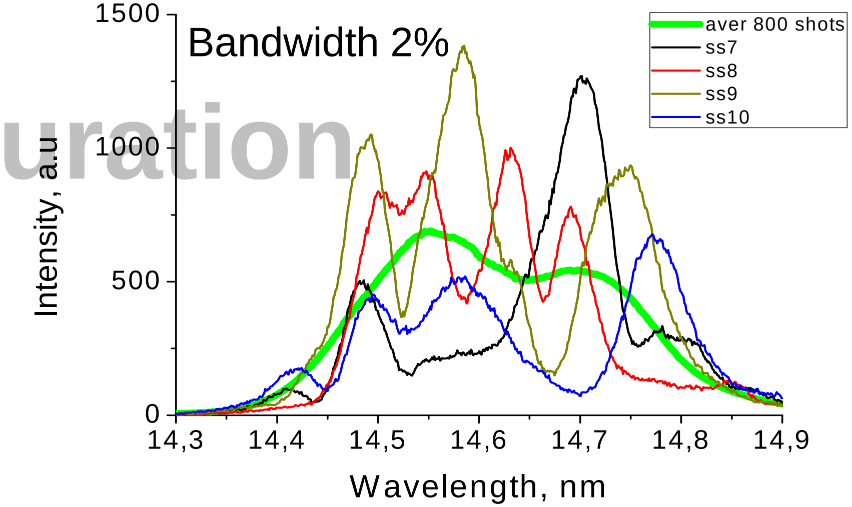
~ 3 - 4 spikes

0.03 nm spike width

t >10 fs FWHM

Saturation





Low charge operation

- Requires new sensors and more sensitive electronics for electron beam diagnostics (charge, position, timing)
- Requires careful tuning of bunch compression using electron and photon diagnostics
- Online monitoring of electron phase space and FEL pulse length not available yet

Measurement of short FEL pulses

- Wanted: monitoring of the photon pulse length
- Experiments to compare different techniques are being performed in a regular manner
- Methods to measure FEL pulse duration being used or tested
  - THz streak camera
    with THz undulator, edge radiation, external laser
  - THz undulator as afterburner (optical replica of the FEL-pulse)
  - High resolution spectrometer
  - Statistical methods
  - Autocorrelation (several set-ups)
  - Cross correlation techniques (e.g. reflectivity)
- Next campaign in weeks 6, 9 and 10

4th User Period - schedule 2012

1	2.Jan - 8.Jan	7	FLASH commissioning		
2	9.Jan - 15.Jan	7			
3	16.Jan - 22.Jan	7			
4	23.Jan - 29.Jan	7			
5	30.Jan - 5.Feb	4	Accelerator studies		
6	6.Feb - 12.Feb	4			
7	13.Feb - 19.Feb	4			
8	20.Feb - 26.Feb	2	FEL studies		
9	27.Feb - 4.Mar	2			
10	5.Mar - 11.Mar	2			**FLS2012**
11	12.Mar - 18.Mar	3		preparation user run	
12	19.Mar - 25.Mar	1	User Run		
13	26.Mar - 1.Apr	1			
14	2.Apr - 8.Apr	1			
15	9.Apr - 15.Apr	2	FEL studies	personnel interlock test, Survey	
16	16.Apr - 22.Apr	2			PETRA interlock test
17	23.Apr - 29.Apr	3		preparation user run	
18	30.Apr - 6.May	3			
19	7.May - 13.May	1	User Run		
20	14.May - 20.May	1			
21	21.May - 27.May	1			**IPAC New Orleans**
22	28.May - 3.Jun	1			
23	4.Jun - 10.Jun	2	FEL studies	Survey	
24	11.Jun - 17.Jun	3		preparation user run	
25	18.Jun - 24.Jun	1	User Run		school holidays HH
26	25.Jun - 1.Jul	1			school holidays HH/SH
27	2.Jul - 8.Jul	1			school holidays HH/SH
28	9.Jul - 15.Jul	1			school holidays HH/SH
29	16.Jul - 22.Jul	5	Maintenance	vacuum work, survey, bypass	**Science at FELs**
30	23.Jul - 29.Jul	2	FEL studies		school holidays HH/SH
31	30.Jul - 5.Aug	2			school holidays HH/SH
32	6.Aug - 12.Aug	3		preparation user run	
33	13.Aug - 19.Aug	1	User Run		
34	20.Aug - 26.Aug	1			
35	27.Aug - 2.Sep	1			**FEL Nara**
36	3.Sep - 9.Sep	1			
37	10.Sep - 16.Sep	4	Accelerator studies		
38	17.Sep - 23.Sep	2	FEL studies		
39	24.Sep - 30.Sep	2			
40	1.Oct - 7.Oct	3		preparation user run	
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42	15.Oct - 21.Oct	1			
43	22.Oct - 28.Oct	1			
44	29.Oct - 4.Nov	1			
45	5.Nov - 11.Nov	2	FEL studies		
46	12.Nov - 18.Nov	3		preparation user run	
47	19.Nov - 25.Nov	1	User Run		
48	26.Nov - 2.Dec	1			
49	3.Dec - 9.Dec	1			
50	10.Dec - 16.Dec	1			
51	17.Dec - 23.Dec	6	Start Shudown 20-Dec-2012		
52	24.Dec - 30.Dec	6			
1	31.Dec - 6.Jan	6			
2	7.Jan - 13.Jan	6			

- 6 blocks with 250 shifts scheduled
- 20 projects selected out of 77 proposals (+5 reserve), plus 4 in-house projects, plus compensation for lost week
- First iteration for detailed schedule of experiments done

main problem: nobody likes to use 1st block

Consequences:

- Time for machine tuning has to be taken from the user shifts
- We need more flexibility in the future

Example schedule of block 6

- Colors indicate different experiments
(8 experiments on 3 beamlines, 4 need optical laser, 3 need THz)
- The schedule is a delicate balance between beamline availability, pump-probe lasers, set-up time, sample changes, and many other constraints

preliminary - first iteration

November - December 2012 / Beamblock 6

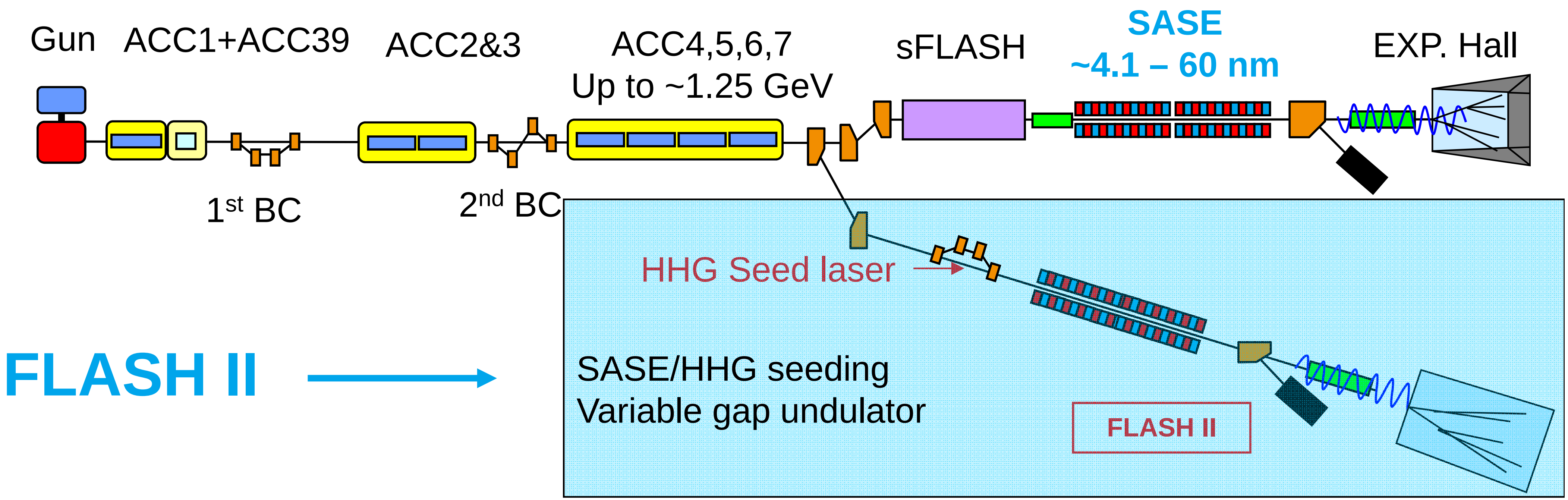
last update: 19.1.2012

L = optical pump-probe laser SD= Split and delay

		day shift (7:00-19:00)					night shift (19:00 -7:00)				
19.11.12	Mo	machine setup for users					Moeller	13.5 nm +/- 0.05 nm	1b., 50-100fs, max pulse energy	BL3	THz
20.11.12	Tu	Wernet	10.1 nm +/- 0.4 nm	1b., 50-100fs, max pulse energy	BL2	L	Wernet	10.1 nm +/- 0.4 nm	1b., 50-100fs, max pulse energy	BL2	L
21.11.12	We	Moeller	13.5 nm +/- 0.05 nm	1b., 50-100fs, max pulse energy	BL3	THz	Moeller	13.5 nm +/- 0.05 nm	1b., 50-100fs, max pulse energy	BL3	THz
22.11.12	Th	Wernet	10.1 nm +/- 0.4 nm	1b., 50-100fs, max pulse energy	BL2	L	Wernet	10.1 nm +/- 0.4 nm	1b., 50-100fs, max pulse energy	BL2	L
23.11.12	Fr	Moeller	13.5 nm +/- 0.1 nm	1b., 50-100fs, max pulse energy	BL3	THz	Moeller	13.5 nm +/- 0.1 nm	1b., 50-100fs, max pulse energy	BL3	THz
24.11.12	Sa	Wernet	10.1 nm +/- 0.4 nm	1b., 50-100fs, max pulse energy	BL2	L	Wernet	10.1 nm +/- 0.4 nm	1b., 50-100fs, max pulse energy	BL2	L
25.11.12	Su	Moeller	13.5 nm +/- 0.1 nm	1b., 50-100fs, max pulse energy	BL3	THz	Moeller	13.5 nm +/- 0.1 nm	1b., 50-100fs, max pulse energy	BL3	THz
26.11.12	Mo	Acremann	20.7 nm +/- 3 nm	300b., 500kHz, 50-100fs, 10µJ	PG2	L	Acremann	20.7 nm +/- 3 nm	300b., 500kHz, 50-100fs, 10µJ	PG2	L
27.11.12	Tu	Maintenance					Maintenance				
28.11.12	We	Maintenance / machine setup for users					Moeller	13.5 nm +/- 0.1 nm	1b., 50-100fs, max pulse energy	BL3	THz
29.11.12	Th	Moeller	13.5 nm +/- 0.1 nm	1b., 50-100fs, max pulse energy	BL3	THz	Acremann	20.7 nm +/- 3 nm	300b., 500kHz, 50-100fs, 10µJ	PG2	L
30.11.12	Fr	Acremann	20.7 nm +/- 3 nm	300b., 500kHz, 50-100fs, 10µJ	PG2	L	Moeller	13.5 nm +/- 0.1 nm	1b., 50-100fs, max pulse energy	BL3	THz
1.12.12	Sa	Moeller	13.5 nm +/- 0.05 nm	1b., 50-100fs, max pulse energy	BL3	THz	Moeller	13.5 nm +/- 0.05 nm	1b., 50-100fs, max pulse energy	BL3	THz
2.12.12	Su	Chapman/DePonte	4.2 nm +/- 0.01 nm	100b., 1MHz, >100fs , max pulse energy	BL2		Chapman/DePonte	4.2 nm +/- 0.01 nm	100b., 1MHz, >100fs , max pulse energy	BL2	
3.12.12	Mo	Acremann	20.7 nm +/- 3 nm	300b., 500kHz, 50-100fs, 10µJ	PG2	L	Acremann	20.7 nm +/- 3 nm	300b., 500kHz, 50-100fs, 10µJ	PG2	L
4.12.12	Tu	Maintenance					Maintenance				
5.12.12	We	Maintenance / machine setup for users					Chapman/DePonte	4.2 nm +/- 0.01 nm	100b., 1MHz, >100fs , max pulse energy	BL2	
6.12.12	Th	Chapman/DePonte	4.2 nm +/- 0.01 nm	100b., 1MHz, >100fs , max pulse energy	BL2		Chapman/DePonte	4.2 nm +/- 0.01 nm	100b., 1MHz, >100fs , max pulse energy	BL2	
7.12.12	Fr	Radu	8.7 nm +/- 0.1 nm	30b., 1MHz, <50fs, max pulse energy	BL3	THz	Radu	8.7 nm +/- 0.1 nm	30b., 1MHz, <50fs, max pulse energy	BL3	THz
8.12.12	Sa	Chapman/DePonte	4.2 nm +/- 0.01 nm	100b., 1MHz, >100fs , max pulse energy	BL2		Chapman/DePonte	4.2 nm +/- 0.01 nm	100b., 1MHz, >100fs , max pulse energy	BL2	
9.12.12	Su	Gerasimova inhouse	18.8 nm +/- 0.1 nm	800b., 1MHz, >100fs , max pulse energy	PG2	L	Gerasimova inhouse	18.8 nm +/- 0.1 nm	800b., 1MHz, >100fs , max pulse energy	PG2	L
10.12.12	Mo	Radu	8.7 nm +/- 0.1 nm	30b., 1MHz, <50fs, max pulse energy	BL3	THz	Radu	23.5 nm +/- 0.1 nm	30b., 1MHz, <50fs, max pulse energy	BL3	THz
11.12.12	Tu	Gerasimova inhouse	18.8 nm +/- 0.1 nm	800b., 1MHz, >100fs , max pulse energy	PG2	L	Gerasimova inhouse	18.8 nm +/- 0.1 nm	800b., 1MHz, >100fs , max pulse energy	PG2	L
12.12.12	We	Radu	8.7 nm +/- 0.1 nm	30b., 1MHz, <50fs, max pulse energy	BL3	THz	Radu	23.5 nm +/- 0.1 nm	30b., 1MHz, <50fs, max pulse energy	BL3	THz
13.12.12	Th	Radu	23.5 nm +/- 0.1 nm	30b., 1MHz, <50fs, max pulse energy	BL3	THz	Radu	23.5 nm +/- 0.1 nm	30b., 1MHz, <50fs, max pulse energy	BL3	THz
14.12.12	Fr	Chapman/DePonte	4.2 nm +/- 0.01 nm	100b., 1MHz, >100fs , max pulse energy	BL2		Chapman/DePonte	4.2 nm +/- 0.01 nm	100b., 1MHz, >100fs , max pulse energy	BL2	
15.12.12	Sa	Chapman/DePonte	4.2 nm +/- 0.01 nm	100b., 1MHz, >100fs , max pulse energy	BL2		setup 20.8 nm				
16.12.12	Su	Stojanovic inhouse	20.8 nm +/- 0.3 nm	1b., >100fs , max pulse energy	BL3	L THz	Contingency / Machine setup				
17.12.12	Mo	Stojanovic inhouse	20.8 nm +/- 0.3 nm	1b., >100fs , max pulse energy	BL3	L THz	Contingency / Machine setup				
18.12.12	Tu	Aquila	13.5 nm +/- 0.2 nm	100b., 40kHz, <50fs, 10µJ	BL2		Aquila	13.5 nm +/- 0.2 nm	100b., 40kHz, <50fs, 10µJ	BL2	
19.12.12	We	Stojanovic inhouse	20.8 nm +/- 0.3 nm	1b., >100fs , max pulse energy	BL3	L THz	Stojanovic inhouse	20.8 nm +/- 0.3 nm	1b., >100fs , max pulse energy	BL3	L THz
20.12.12	Th	Aquila	13.5 nm +/- 0.2 nm	100b., 40kHz, <50fs, 10µJ	BL2		Aquila	13.5 nm +/- 0.2 nm	100b., 40kHz, <50fs, 10µJ	BL2	
21.12.12	Fr	Stojanovic inhouse	20.8 nm +/- 0.3 nm	1b., >100fs , max pulse energy	BL3	L THz	Stojanovic inhouse	20.8 nm +/- 0.3 nm	1b., >100fs , max pulse energy	BL3	L THz

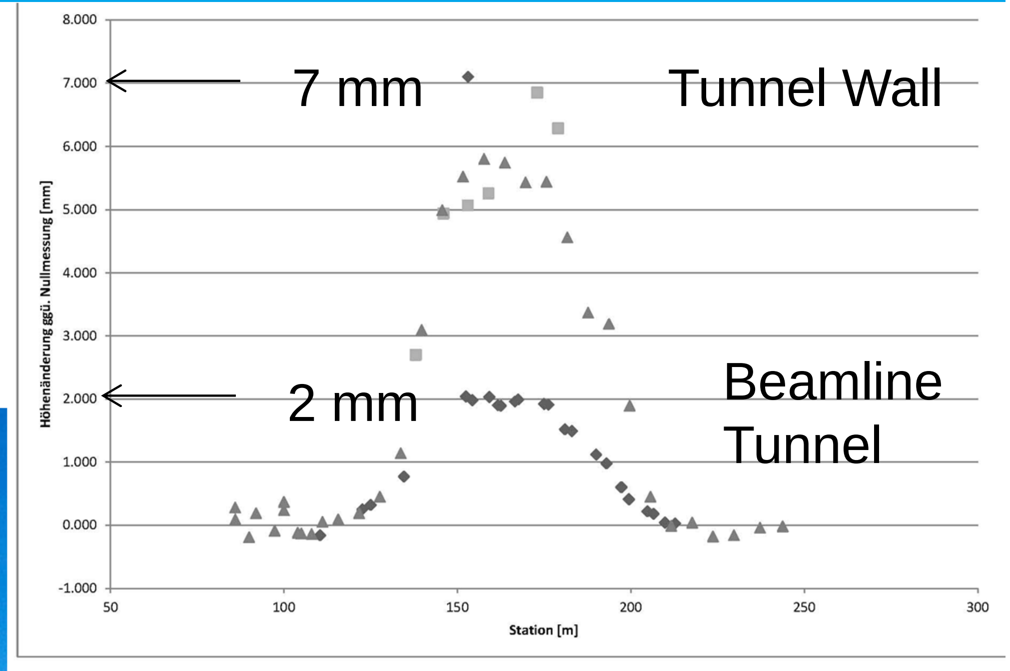
The FLASH II project

- 2nd FEL in a new tunnel and new experimental hall
- Electron beam switch behind last accelerator module
- Tuning of FLASH2 by changing undulator gap
- Employing SASE and HHG seeding



Civil Construction started in Sep 2011

Movement
- Tunnel Wall
- Components



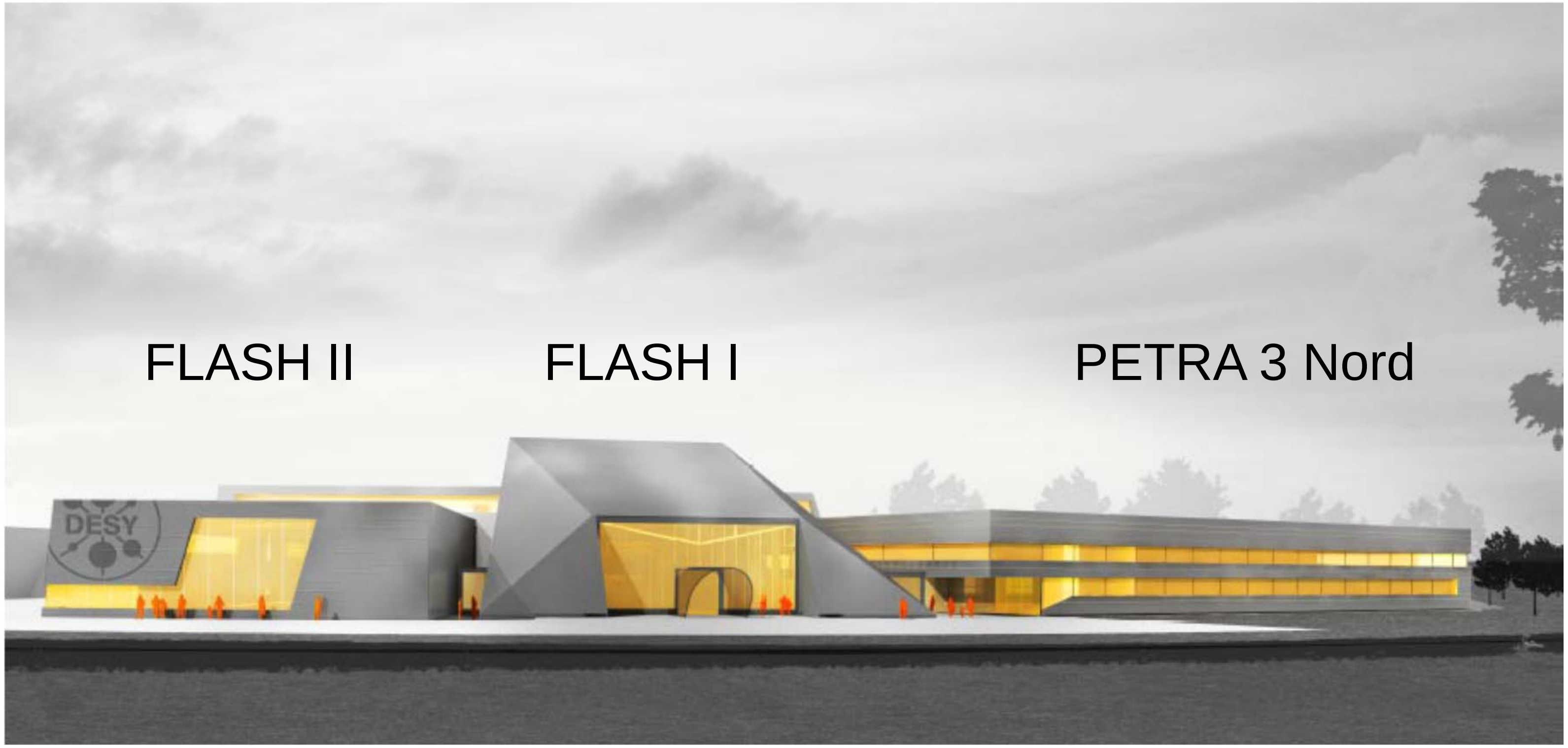
Construction of FLASH II - Sep 2011

Construction of FLASH II - Nov 2011

Construction of FLASH II - Dec 2011

Construction of FLASH II - Jan 2012

FLASH in 2014



The future FLASH facility from the North

from the Sout
(walking on the FLASH tunnel)

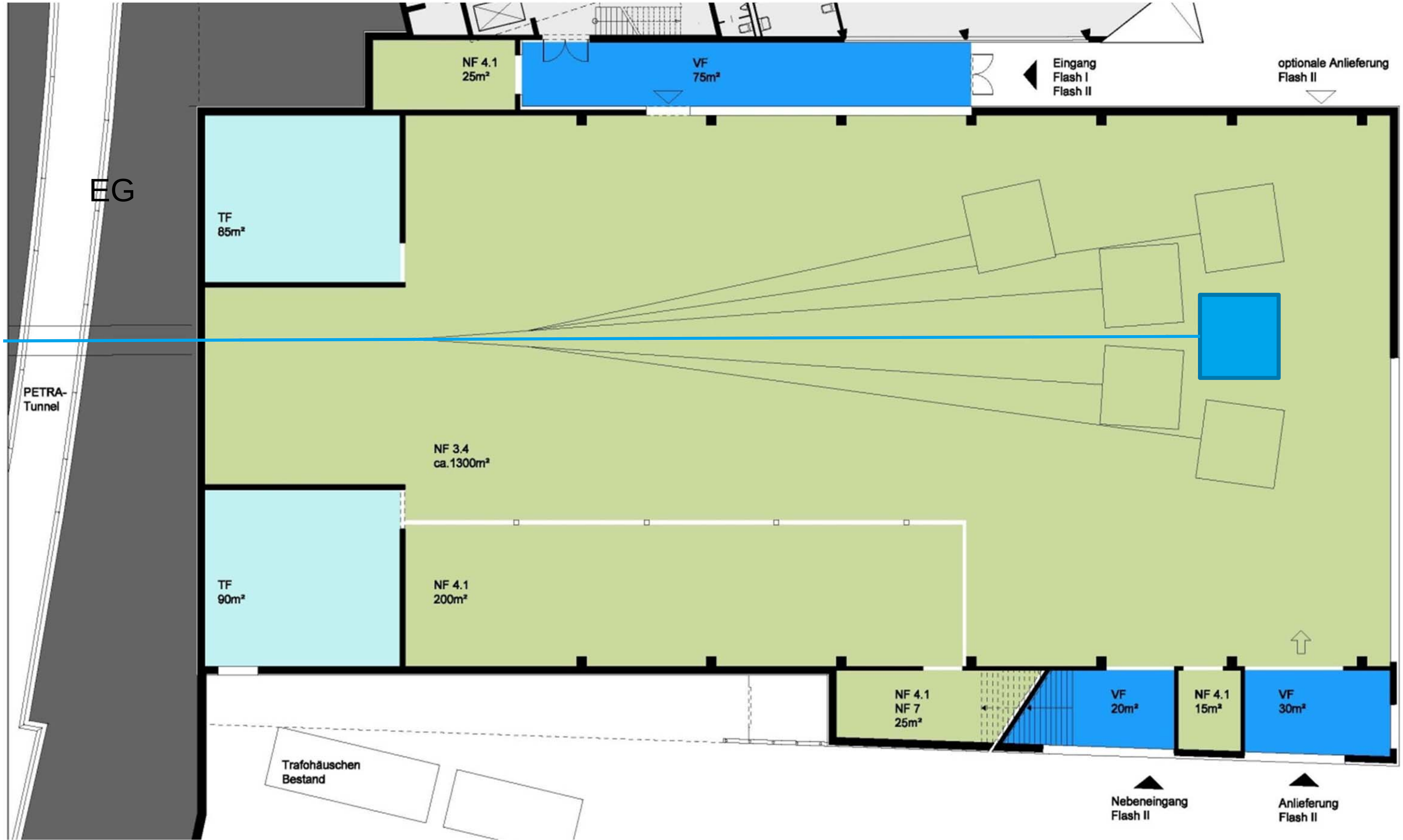
Time schedule FLASH II

Taking into account - PETRA III and DORIS runs
- XFEL and PETRA Upgrade construction

- Civil Construction Tunnel started in September 2011
(3 month FLASH1 shutdown Sep-Dec 2011)
- Installation of hardware starting autumn 2012
- Connection FLASH1 + 2: Winter / Spring 2013
(FLASH1 shutdown)
- Technical commissioning starting spring 2013
- Experimental hall construction starting summer 2012

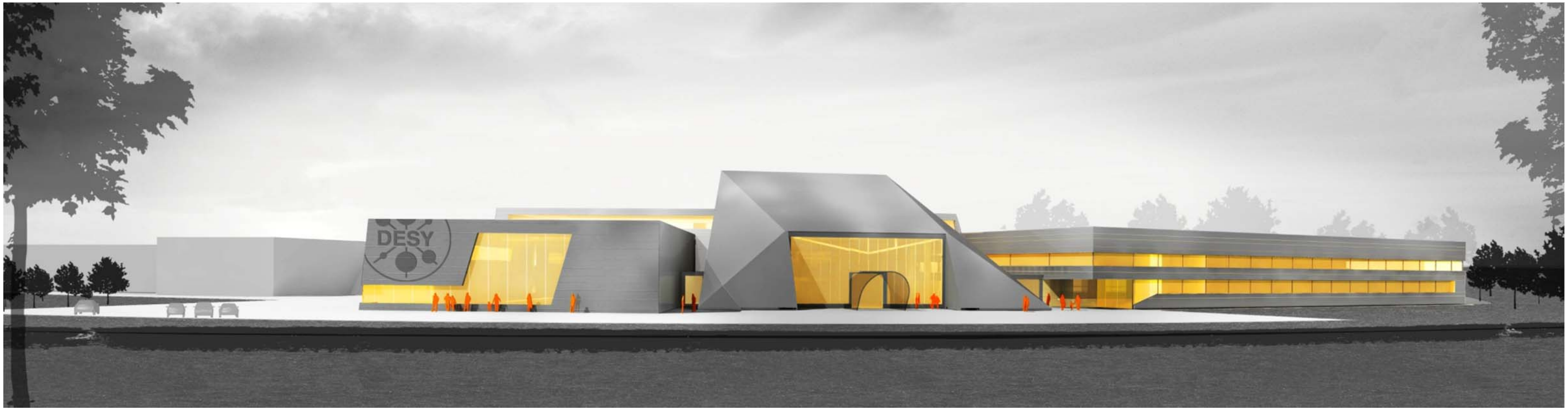
New experimental hall - in 2014

Only the centre beamline is in the FLASH II budget



„New Science Opportunities with FLASH“ Workshop

October 12 -14, 2011.



- **Over 150 participants**
- **20 user talks and over 40 posters, 10 facility talks**
- **1st day: Presentation of news from FLASH and status of FLASH II project**
- **2nd and 3rd day: Highlights of research at FLASH and proposals for permanent end stations for FLASH 2**

HELMHOLTZ GEMEINSCHAFT

DESY

Workshop summary

- First discussion of the scientific perspectives and possible permanent end stations with the user community
- Should be continued in order to make use of the upcoming BMBF Verbundforschung funding period in a coordinated way (Dec 2012)
- There is a strong interest in studying magnetic and biological materials
  => <1.5 nm wavelength with variable polarisation; water window
- There is a strong demand for ultrahigh temporal resolution (~10 fs)
  => synchronisation, seeding, diagnostics for jitter and pulse duration
- We need to develop a medium-term scenario for FLASH as a whole

Further development of FLASH

after FLASH2 is operational with a few beamlines:

- New FLASH1 undulator with shorter period, variable gap and variable polarisation
- Further energy upgrade to ~1.5 GeV (exchange of modules)

later possibly:

- FLASH3 option (extraction and beam dump prepared)
  - will depend on user demand in the future
  - could provide long wavelengths: ~8 – 80 nm
- Increased duty cycle

Possible long-term scenario for FLASH

	FLASH1	FLASH2	FLASH3
Energy (GeV)	0.7-1.6	0.7-1.6	0.7-1.6
Peak current (kA)	2.5	2.5	2.5
Charge (nC)	0.5	0.5	0.5
Normal. emittance (mm mrad)	1.0*	1.3	2.0
Energy spread (MeV)	0.2	0.5	1.0
Wavelength range @ 1.6 GeV	1.5 – 2	2.5-6.5	8-12
Undulator period (mm)	23	31.4	36
Minimum gap	10	9	9
Saturation length	<36	<30	<20
Total wavelength range**	1.5 – 10	2.5 – 40	8 – 80

by Bart Faatz

* new gun klystron needed to get 60 MV/m gradient → 1 mm mrad emittance
** 0.7 – 1.6 GeV

Summary

- The 3rd user period was a great success – from the operational point of view, after a long shutdown with many significant changes
- FLASH operation is more stable and reliable than ever (uptime 96 %)
- Many things are being improved or developed, e.g. reliable operation with very short pulses (<50 fs FWHM) together with many pulses per train and synchronization to the level of the pulse length
- FLASH II is making progress, but some delays are foreseeable due to too many other parallel projects
- The further development of the facility is under discussion with the user community; we should coordinate the applications for BMBF funding ("Verbundforschung") to support the construction of new beamlines and experimental stations

- science-at-FELs-2012.desy.de
- **July 15-18, 2012**
- **Abstract submission deadline: extended to Feb 6, 2012**
- **Registration deadline: April 30, 2012**